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ABSTRACT

This report tells of the procedures and results of a psychophysical study of 28 3.8-year-old-boys from the Harlem Training Center. In spite of an experimental situation that was something of an ordeal, some meaningful data was generated. The main area investigated in this study was the evoked-response indices of temporal processing, that is, the recordable response of visual cortex to single flashes and pairs of flashes. The flash pairs were presented with varying inter-flash intervals. Stimuli consisted of pulses of light provided by a Grass PS-2 photostimulator. Dependent measures of subject responding were derived from monopolar recordings that were taken from the right occipital region centered between midline and ear. Computer memory was fed to a Mosley X-Y plotter, which provided permanent ink records of the data. Several findings are reported but the main conclusions concern relations between children and adults regarding the visual evoked response: (1) the time required between successive stimuli for the emergence of coherent cortical responses is longer in children than in adults and (2) backward masking or inter-stimulus interference is much more pronounced in children. (Author/MH)

SOME CHARACTERISTICS OF NEURAL PROCESSING IN THE CHILD*,[1]

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[2]This research was completed while the author was still with the Electronics Research Labs., Columbia Univerisyt, which is acknowledged for providing support personnel and facilities.

SOME CHARACTERISTICS OF NEURAL PROCESSING THE CHILD

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The research to be reported was conducted with male children, all 3.8 years of age, drawn from the subject population of the Harlem Training Center. In the presentation following mine, Dr. Palmer will describe relevant characteristics of these children. For the present purposes, it is sufficient to point out that the children were chosen because of their availability, because they formed an age-group of considerable interest and because an extensive psychometric profile of each child existed. Matching these advantages, however, were certain restraints and handicaps which affected the research to an undefinable degree. First, as subjects in a much larger and more ambitious undertaking, the children were available for testing in the present study only once. Moreover, by virtue of their age and of the less than ideal physical surroundings of the test room, it was clear at the outset that only a minimum number of trials and conditions could be employed. 318 year-old children, unencumbered by a compulsion to explore the central nervous system, are quite honest in their reactions to a small cubicle filled with tubes, lights, recorders and strangely serious adults weraring suite and ties in the middle of a Harlem summer. Thus, of the fifty children run through all conditions, useful data were obtained from twenty-eight. The others were either too smart to sit through the ordeal or, if cajoled into staying, engaged in the kind of time-filling behaviors that characterize both children and noisy records. Again, out of respect for the research objectives of the Harlem Training Center, we avoided any form of behavior control that risked alienating the child from the Center.

Pilot research with siblings of the ultimate sample indicated that something between 30 and 45 minutes of testing were about all that we could count on. Given this, trade-offs had to be made between conditions and trials. Our principal interest was in evoked-response indices of temporal processing--the recordable response of visual cortex to single flashes and to pairs of flashes, the latter presented with different inter-flash intervals. Any meaningful relationship between properties of the evoked response and temporal features of the stimulus require a representative range of intervals. In our research, in addition to single flashes, we presented flash-pairs with each flash separated from the next by either 40, 80, 160 or 320 milliseconds. Ellingson (1960) has shown that, with infants, the time necessary between successive presentations of single flashes to get discrete responses varies inversely with age. Based upon his data, we chose presentation rates of one per 2.5 seconds. In order to complete five conditions within 30-45 minutes with presentation rates as slow as this, we were limited to fifty trials per condition or three hundred per subject, since a sixth CONTROL condition was also assigned; one in which all stimulation and recording equipment remained operative but the light was masked from the child's view.

Stimuli consisted of single or paired rectangular pulses of light provided by a Grass PS-2 photostimulator. Pulse to pulse variations in luminance are a well-known limitation of this instrument and no measures were taken to control such contaminants. Rather, flashes were diffused by an inserted diffusing material and were passed through a one-inch aperture viewed at 18 inches. The stimulator setting was fixed at MEDIUM and, with the diffuser and aperture, flashes of approximately 50 milli-lamberts were provided. Tektronik waveform and pulse generators controlled the inter-flash intervals separating each member of a flash-pair and the recycle time of 2.5 seconds.

Monopolar recordings were taken from the right occipital region centered between midline and ear. The reference electrode was fastened to the subject's earlobe was amplified by a differential amplifier and averaged by the Mnemotron Computer of Average Transients, or CAT. For some subjects, a Fabritek averaging computer was employed and, by and large, provided better results. The computer memory was fed to a Moseley X-Y plotter which provided permanent ink records of the data.

The data analyses included conventional measures of latency and amplitude of the various components of the averaged evoked response. Several nomenclatures are currently in use. In the main, we have followed Dustman and Beck (1965) who have isolated eight discriminable components in the first 300 milliseconds following photic stimulation. In their system, the first negative peak is A, the first positive peak B, the next negative C, and so forth. All components are usually not present in every subject. In our research, system noise and subject noise conspired against easy delineation of all components. An adequate picture of the range of data quality can be gained from Fig. 1. With the use of transparent templates, a light box, a little faith and a lot of patience, even the noisiest recordings can be deciphered reliably. By reliably, I mean that several people invoking the same judgmental criteria will arrive at virtually identical values. When this failed to happen, trace was rejected.

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Insert Fig. 1 about here

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This figure presents data from three children under each of the five experimental conditions; from top to bottom, single flash, and pairs separated by 40,80, 160 and 320 milliseconds. Each trace is 500 milliseconds in duration. The large peak evidenced early in nearly all traces is the E-wave component which appeared in about 90% of all traces under all conditions. Let me point to a rather clear record and indicate the major components. (Smith's trace: Waves A--H).

What we were after in all of this was an evoked response analogue of two-

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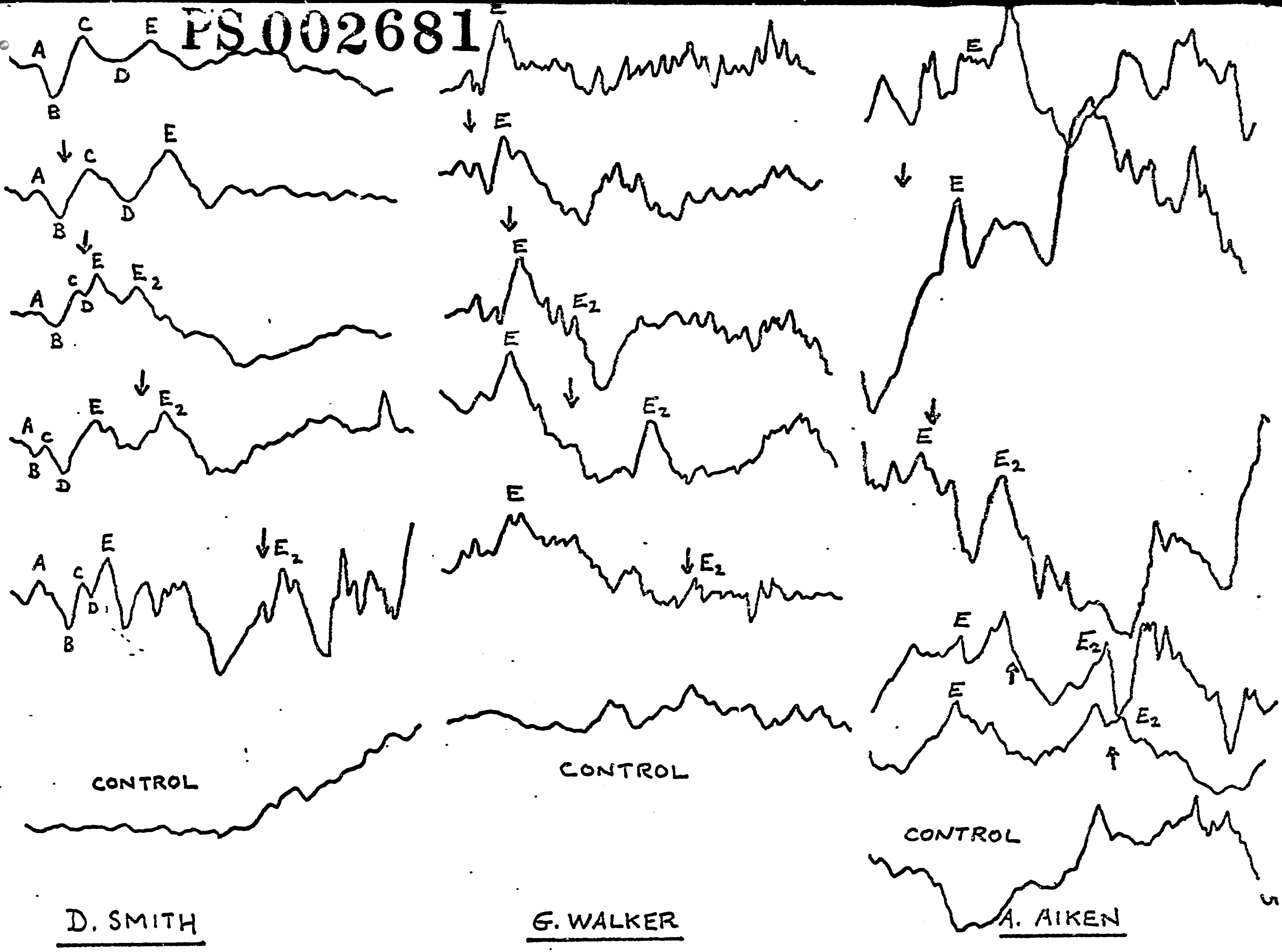

Fig. 1

flash summation, two-flash resolution and two-flash interference. Such phenomena are well represented in the psychophysical literature and are useful in describing temporal aspects of information processing. Donchin et al. (1963) and Ciganek (1964) have reported results from adults using the evoked response and they find reasonable agreement with psychophysical; i.e., verbal report, data. In the present study, we have used reductions in the latency of a single response to a flash-pair relative to a single flash as evidence of summation. That is, if the latency of a given wave is less when a pair of stimuli occurs than when a single flash is presented and if only one response is evident, then we assume that the system has treated the pair as a single flash of greater energy. The more obvious rationale for this assumption is found in the inverse relationship between evoked response latency and luminance. Temporal resolution is simply the presence of two definable responses to two flashes with the former occurring within expected latency ranges. And, finally, two-flash interference or masking is inferred either when components occur later under two-flash than under single-flash conditions or fail to occur at all. We can see some of the effects in Fig. 2. The ordinate is the latency of a given component of the evoked response; the abscissa, the temporal

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Insert Fig. 2 about here

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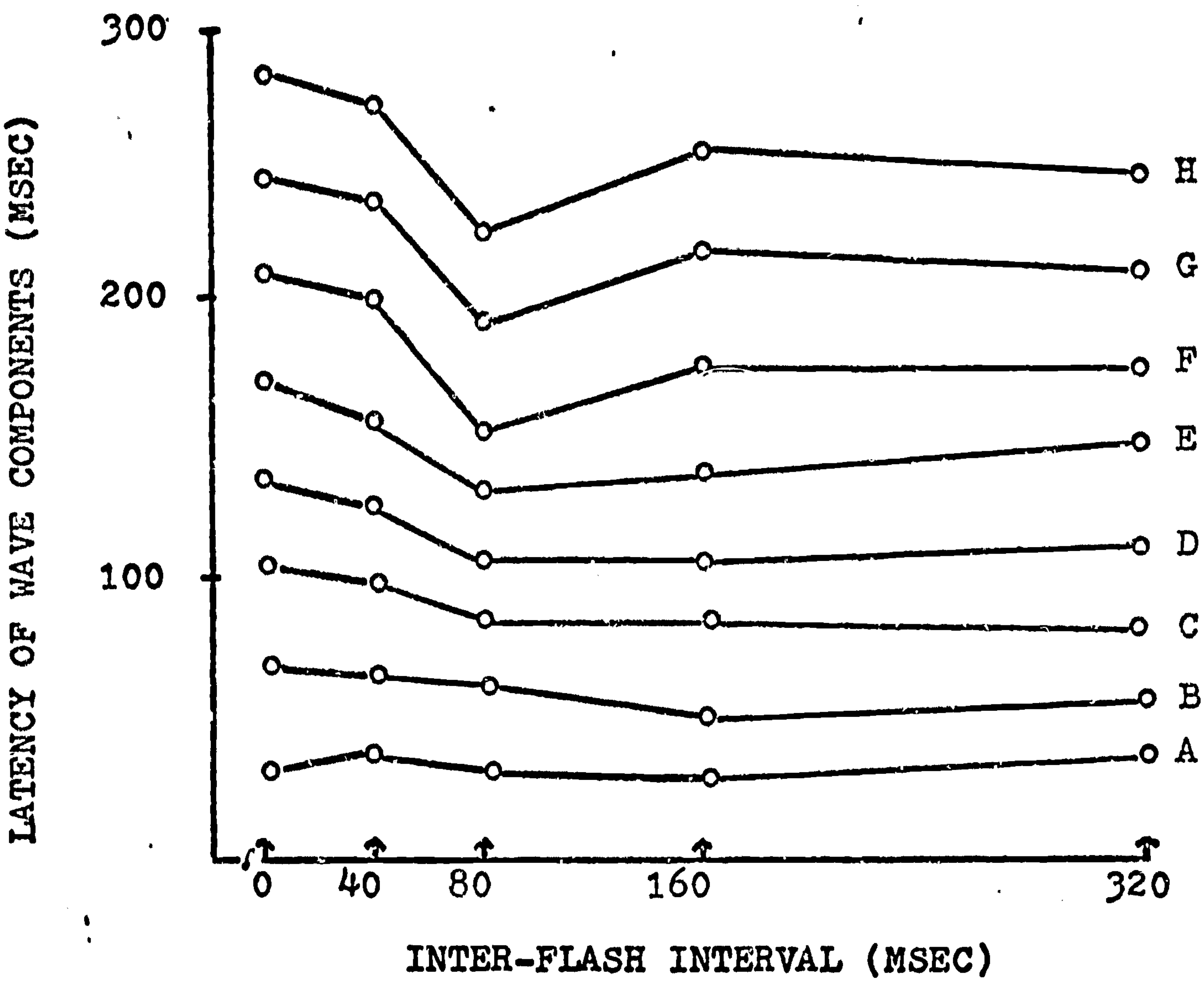
characteristics of the stimulus. Each of the eight components is presented as a parameter. You will observe in the figure that the earliest components, A and B, are little affected by the presence of a second flash. However, later and later components show increasing summation from zero to 40 milliseconds to 80 millisecond intervals. Beyond 80 milliseconds, latencies increase, some disproportionately, indicating a type of relative interference or incomplete summation. Now, this figure is based only upon records in which the various components are

Fig. 2



LATENCY OF WAVE COMPONENTS (MSEC)
300
200
100
0
40
80
160
320
INTER-FLASH INTERVAL (MSEC)
H
G
F
E
D
C
B
A

discernible and measureable and therefore, by its nature, the Figure omits the masking effect.

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Insert Fig. 3 about here

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In this figure, we see the per cent of the records NOT yielding certain components under the various stimulating conditions. The curves show the effects upon the latest component, H; the major component, E; and an average across all components. It should be noted that these effects are upon responses to the first flash only under paired-flash conditions. Another measure of the same interference effect is found in the per cent of E-waves evoked by each flash under all conditions. In Fig. 4 it can be seen that only one flash is responded to at an

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Insert Fig. 4 about here

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inter-flash interval of 40 milliseconds. Arbitrarily, I have assigned zero per cent to the curve of responses to the second stimulus at the 40 millisecond interval. In point of fact, there was no way to determine which of the flashes was not responded to although E-wave latencies are shorter under paired-flash conditions so there may be a basis for concluding that it is the second which is responded to with the first backwardly masked. This is consistent with Donchin, Wike and Lindsley (1963). As you can see, with greater temporal separation, second-flash effects dissipate.

In addition to the foregoing, information is present in the effects of one flash upon the strength of responses to one presented close to it in time. Ciganek (1964) has expressed this relationship in the form of an Excitability Index which is the ratio of the amplitude of the second to the amplitude of the first evoked response. We have computed this ratio for all subjects who provide measurable

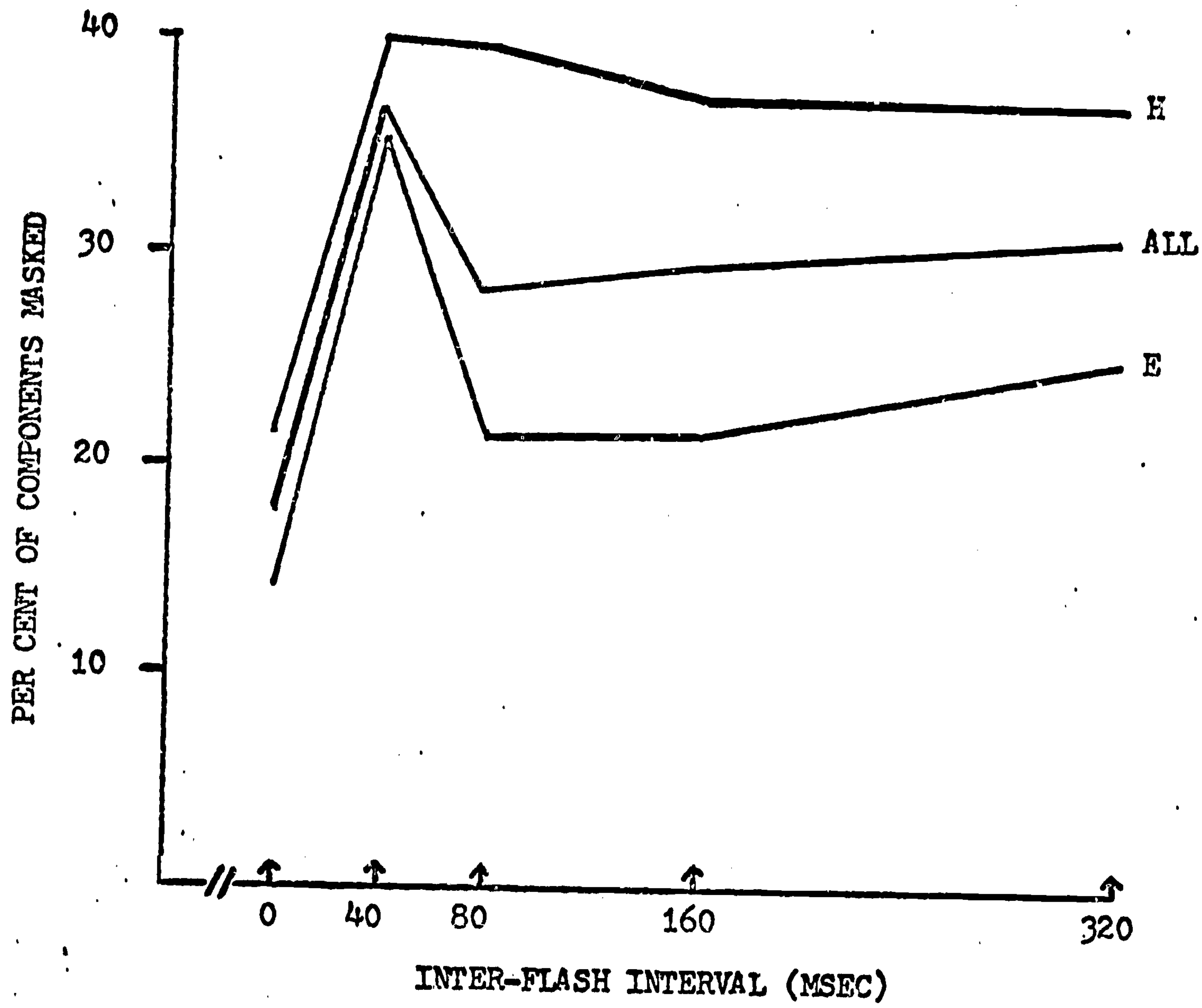
40
30
20
10
PER CENT OF COMPONENTS MASKED
H
ALL
E
0
40
80
160
320
INTER-FLASH INTERVAL (MSEC)

Fig. 3

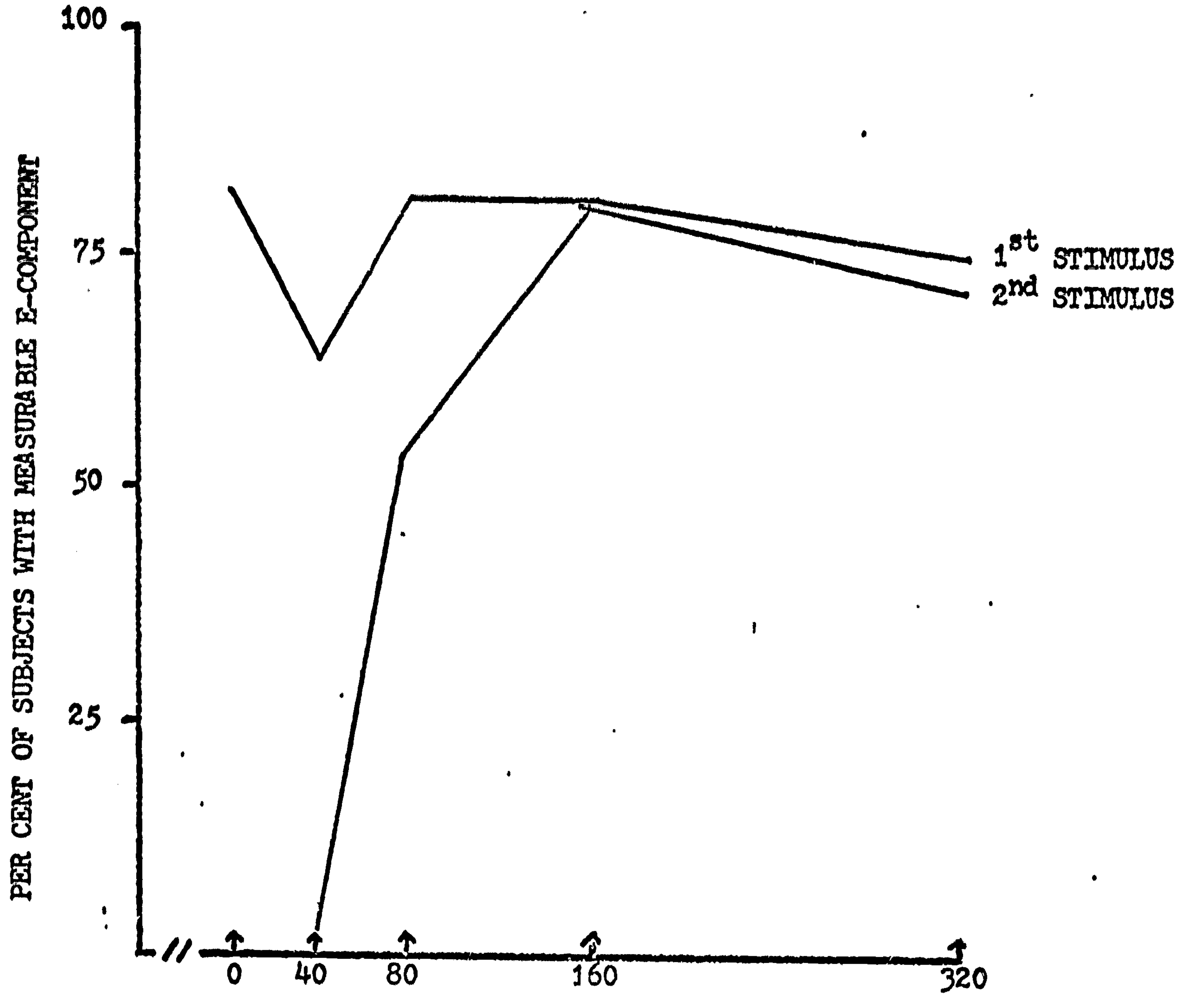
PER CENT OF SUBJECTS WITH MEASURABLE E-COMPONENT
100
75
50
25
0
40
80
160
320
INTER-FLASH INTERVAL (MSEC)
1st STIMULUS
2nd STIMULUS

Fig. 4

E-waves in their evoked responses to both flashes. In Fig. 5 the obtained

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Insert Fig. 5 about here

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Excitability Indices are compared with those reported by Ciganek, using an adult population. Note that the ordinate should be R_2/R_1. Ciganek's intervals were 50, 100, 150, 200 and 250 milliseconds. We have no intervals comparable to hiw 200 and 250. However, the general form of the relationship up to 160 milliseconds is similar. The children show neither the degree nor reliability of excitability as that found in adults, although they do reveal a depression of excitability at long intervals and a kind of facilitation at intervals near 100 milliseconds.

Use of visual evoked responses in studies of visual recovery or visual temporal resoltion is, of course, not new. Donchin and Lindsley (1965), Ciganek (1964) and Schwartz and Shagass (1964), to mention a few, have explored the applicability of such measures of visual function in adults. Dustman and Beck (1966) have studied age effects specifically but have not as yet reported studies employing multiple stimuli. In begging, borrowing and stealing from this constellation of research, we may summarize relations between children and adults as regards the visual evoked response.

First, the time required between successive stimuli for the emergence of coherent cortical responses is long in children relative to adults. In the present research, retroactive influences persist even at separations of 320 milliseconds. If we view this in the context of EEG dependence upon age, we obtain yet another indication of the relatively low-frequency operating characteristics of the young and developing CNS.

Second, backward masking or inter-stimulus interference is much more pronounced in these children. Where adults will show a slight shift on the latency

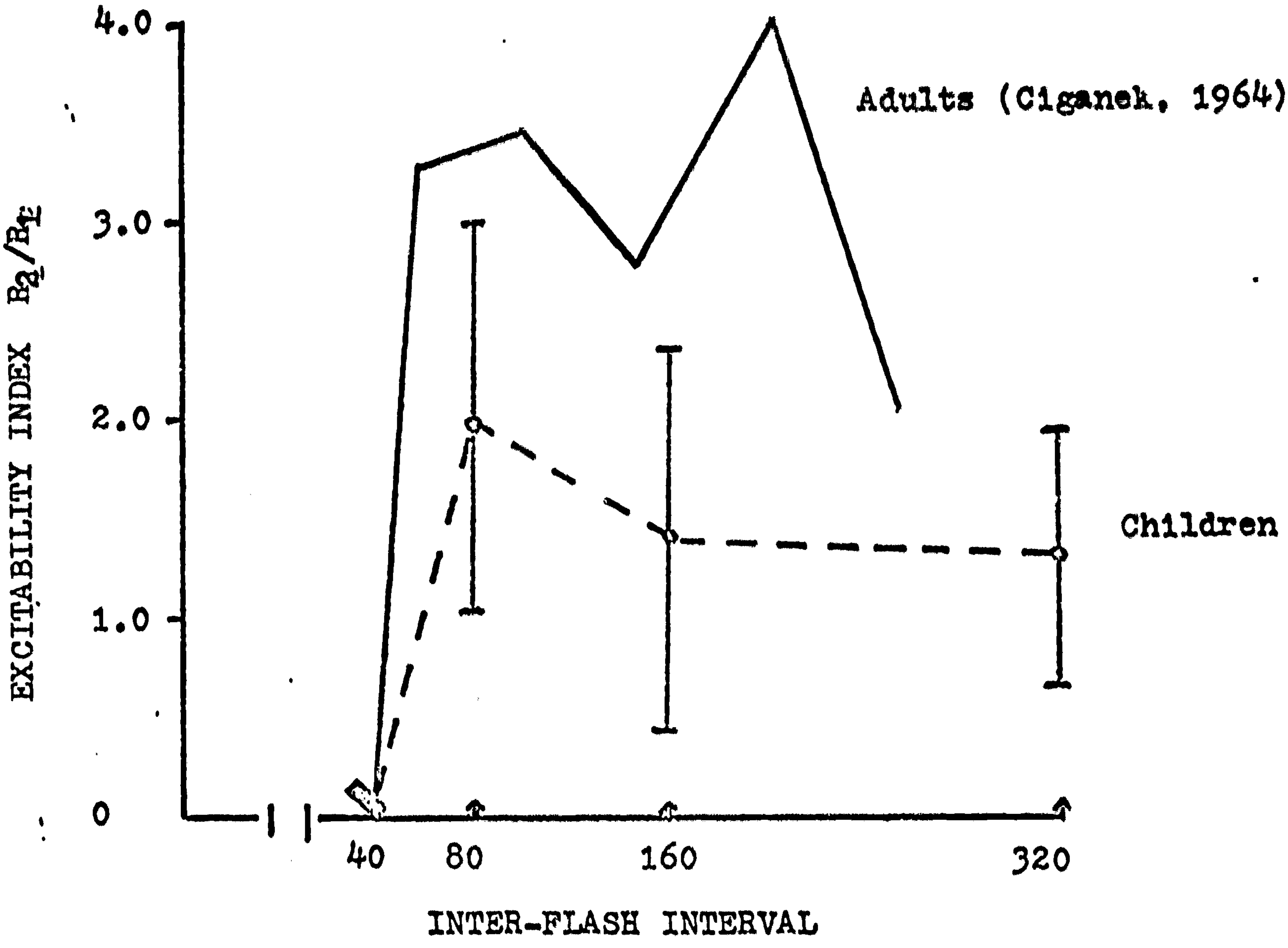
4.0
3.0
2.0
1.0
0
EXCITABILITY INDEX B_2/B_1
40
80
160
320
INTER-FLASH INTERVAL
Adults (Ciganek, 1964)
Children

Fig. 5

continuum, children reveal the total obliteration of a component or even of the entire evoked response. The implied distinction between specific and diffuse mechanisms and the temptation to discuss reduced channel capacities are too great to defer.

Third, and I know that Dr. Palmer will have more to say on this, there is the matter of employing these data and methods in assessing development. The present experiment was, in major respect, a PSYCHOPHYSICAL study. We've been engaged for some time in research concerned with the processing of multiple and brief visual signals (Robinson, 1966, 1966, 1967, 1968). This research has suggested certain functional characteristics of the peripheral and central ends of the visual system. Our use of children was prompted by the same considerations that cause electrophysiologists to look for cortical receptive fields in kittens, once finding them in adult cats! Our use of averaged evoked responses was dictated by the unreliability of the verbal reports of children. Thus, we chose a response indicator which makes no assumption about conceptual, cognitive or linguistic ability. For the most part, our decisions proved satisfactory. In a preliminary way, we're satisfied that the techniques employed allow a broad range of visual psychophysical studies and thereby permit indirect assessments of developing sensory systems. Whether one can go from this to more complicated neural processes is moot. E. Roy John et al. (1967) have offered convincing evidence that the averaged evoked respon differs reliably when different geometric forms are employed. Following Gray Walter's lead (1964), Low and his collaborators (1966) have added to a growing literature on relations between averaged D.C. shifts in the evoked response and the formation of learned associations. In the Nineteenth Century, Galton failed to learn much about intelligence by measuring sensory thresholds--although he learned a good deal about the senses. What the evoked response tells us about the developing child will depend upon the relevance of the selected measures to the complex behavior they are presumed to underlie.

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